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Assessing irrigated agriculture in Sokoto-Rima River Basin, Nigeria

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ABSTRACT

Inadequate water supply is a major problem to the flourishing of agricultural activities in most parts of the world, especially the semi-arid regions. The study examined irrigated agriculture in Sokoto-Rima River Basin, Nigeria. Cluster sampling technique was used to administer questionnaire to 450 farmers who were sampled from 15 farm settlements in three agricultural zones while frequency counts, percentages, and pairwise t-test were used for data analysis. It was found out that 48.9% of the farmers engaged in irrigation farming, out of which 35.56% used a single source of water supply. Hand-dug wells and rivers were the most important water supply sources. Irrigation varied from one to three methods and has increased in practice by 14% from 34.7% in the 1970s to 48.7% in 2000s. Five single/combined methods of the 1970s no longer exist while 7 new ones emerged. Calabash (19.3%) and Sprinkler (16.4%) were the most widely used methods in the 1970s and 2000s respectively. Pairwise t-test showed no significant difference between the irrigation methods in the 1970s and 2000s ($t(20) = -1.95$, p 0.05, $CI_{0.95}$ -15.55, 9.25). Thirty-two percent farmers irrigate during the wet season; 30.4% irrigate when there is no rain for long; 28% experienced rainfall after irrigation but 22.1% noted negative consequences on their crops, with the destruction of crops after falling down taking the lead. Farmers' experience varied from 1 to 5 years to over 21 years but most farmers had the highest experience. Conclusively, irrigation farming has increased in the River Basin recently. An accurate irrigation planning will aid agricultural productivity.

Keywords: Farmers: irrigation; semi-arid Nigeria; water application; water supply

INTRODUCTION

Water is one of the basic needs of life and the most valuable natural resource due to its scarcity in most part of the world. Freshwater is the most useful water resource due to its non-saline nature. It is made up of 2.28% of world water 1.37 x 10^8 million ha-m (Raghunath, 2006; 2007). Only 0.35% (0.05% of surface water and 0.3% of groundwater) is available for use. The remaining 2.15% fresh water is retained in glacier and ice caps while 0.3% is unavailable as it is below a depth of 800 m (Raghunath, 2006). Not less than nine percent of the global fresh water resides in Africa (UNESCO, 2016; Negm, 2017; Rosenberg, 2017).

Agricultural water extractions to the total water extraction differ in various regions of the world. It is 44% of total water withdrawals in Organization for Economic Co-operation and Development (OECD) countries, 74% in Brazil, Russian

Federation, India and China (BRIC) countries and more than 90% from rivers, lakes and aquifers in the least developed countries (LDCs) (FAO, 2011). FAO (2017) reported that agricultural water use varied from 80 to 90 percent in North Africa, the Middle East, and Central Asia, India and China because of low rainfall. The growth in population since the 1960s resulted in a three-fold increase in water extraction and there is a likelihood of 1–2% in the rate of yearly increase in the future (UNESCO-WWAP, 2012; Re *et al.,* 2017). The United Nations World Water Development Report (2016) revealed that the world irrigated regions that depend on groundwater is 38% and this has raised agricultural water use ten times since the 1960s.

The increased requirement for food and the expansion in agriculture witnessed in the 1970s resulted in a rapid increase in irrigation development (World Water Assessment Programme, 2009). Irrigation accounted for 67% of the world's total groundwater withdrawal in 2010 (1,000 km^3 per year) while domestic and industrial purposes accounted for 22% and 11% respectively (IGRAC, 2010; Siebert *et al.*, 2010; FAO, 2011).

Global irrigation practice has a long time history. The earliest methods used include flood irrigation in Egypt, underground canals in ancient Sri Lanka in 300 BCE, chain pumps in China in 6th century BCE, irrigation canals in Peru in 4th millennium BCE and America in 1200 BC to AD 150 and so on (Needham, 1986; Seok-gi 1987; Encyclopedia Britannica, 1994; de Silva, 1998; Dillehay *et al.,* 2005; Frenken, 2005). However, irrigation practice in Sokoto-Rima River Basin started in Kware in northern Nigeria (now Sokoto state) in 1926 (FMWR, 1991). The methods of irrigation in the basin include both traditional and modern irrigation technologies - calabash, watering can, sprinkler, drip, flood, gravity and tube-wells. Most of the commonest irrigation methods used in the past including calabash and flood are still in use today. Yahaya (2002) reported that gravity, calabash and bucket irrigation were among some of the traditional methods used in various farms in northern Nigeria. However, Cox and Akin (1979) noted that contemporary irrigation methods in use include surface, drip, corrugation and sprinkler irrigation among others**.**

Research has shown that water is the bedrock for the production of food, as agriculture uses 75 to 90% of non-saline water in an area (The World Water Organization, 2010). To this end, irrigated farming made-up of twenty percent of cropped land and is responsible for forty percent of the world production of food (UNESCO-WWAP, 2012). Water scarcity may hinder food production, cause food insecurity, increased food prices, disrupt the supply of agricultural raw materials, and increase dependence on food imports, lead to malnutrition, famine and poverty. Therefore, it is desirable to investigate the irrigation water supply, methods, application of water and farmers' experience. The objectives are to (1) investigate the sources of water supply; (2) examine the methods of irrigation; (3) analyze irrigation water application; (4) determine the consequences of rainfall on irrigated crops during the wet season; and (5) examine the farmers' experience on irrigation farming in the study area.

MATERIALS AND METHODS

The Study Area

Sokoto-Rima River Basin is situated between 10.8^{o} and 13.58^{o} North and longitude 3.30^{o} and 7.13^{o} East (Fig. 1) and exhibits a tropical climate, with a definite and distinct wet and dry seasons. The tropical maritime and continental air mass dominates the entire basin during the wet and dry seasons respectively. The wet season is between May and September in the southern part and June to October in the north (Adejuwon, 2017). The rainfall pattern in Sokoto-Rima Basin is a good reflection of the seasonal variation of the surface location of the inter-tropical discontinuity (ITD); the rainfall is single maxima in character. Annual rainfall amount varies from 650 mm to 1013 mm decreases in both duration and amount from the south northward (Emielu, 2000; Adejuwon, 2015). The mean annual temperature is 34.5^{o}C while mean annual temperature range is between 5^{o}C and 10^{o}C.

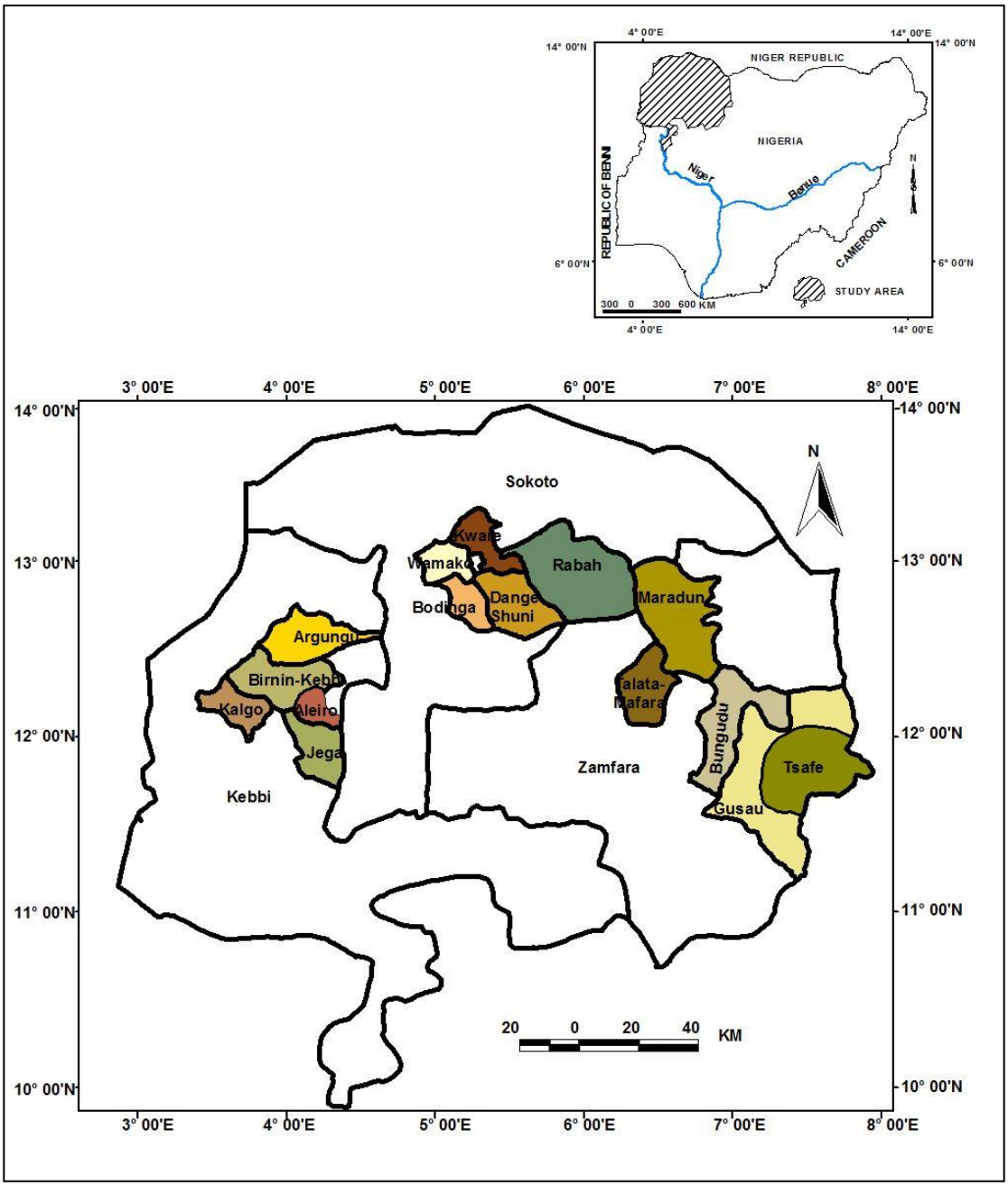

Fig. 1. Selected Local Governments Areas where the questionnaire was administered.

Data collection, Sampling and Analysis

Primary data was obtained for this study through a field investigation, involving direct interactions with the farmers. A well-structured questionnaire was used to elicit information on sources of water supply and methods of irrigation. Cluster method of sampling was used in choosing 450 respondents from 15 farm settlements in three agricultural zones (Sokoto, Kebbi and Zamfara) in Sokoto-Rima river basin. The first stage was the purposive selection of Sokoto, Kebbi and Zamfara zone in the study area. The second stage was the

systematic selection of the 15 local government areas (Table 1). The third stage was the purposive selection of farmsteads. The fourth stage is the random selection of 30 farmers from each of the selected farmsteads. The interviewed farmers were 40 years and above and have been in the farming practice for at least 30 years. Data were analyzed using frequency, percentages and pairwise t-test. A pairwise t-test was used to determine the difference in irrigation methods used in the 1970s and 2000s.

Table 1: Locations of primary data collection in Sokoto-Rima River Basin

State	Local Government	Community
Sokoto	Wamakko	Gumbi
	Bodinga	Mil Goma
	Dange Shuni	Dange
	Kware	Durbawa
	Rabah	Maikujera
Kebbi	Kalgo	Kalgo
	Birni-Kebbi	Gulumbe
	Aliero	Dakala
	Jega	Basaura
	Argungu	Alwasa
Zamfara	Talata Mafara	Tunfafiya
	Gusau	Madidi
	Maradun	Dosara
	Bungudu	Tazame
	Tsafe	Tsafe

RESULTS

Sources of irrigation water supply in Sokoto-Rima River Basin are shown in Table 2. Forty-nine percent (48.9%) of the farmer's in the river basin practices irrigation farming, out of which 35.6% uses a single source of water supply, and 13.3% used more than a source. The single source of water supply varied from earth dams (0.2%) to rivers (13.1%); two sources varied from Rivers and Tube Well (0.4%) to Rivers and Hand-dug Well (6.0%) while three sources of rivers, hand-dug well and borehole was 2.9%. The total of each source of irrigation ranged from 0.2% of Earth dam to 24.9% of hand-dug wells (Table 3).

Table 4 shows the method of irrigation in Sokoto-Rima River Basin. Irrigation varied from one to three methods and practised by 34.7% respondents in the 1970s and 48.7% in 2000s. In 1970s, one method varied from 0.4% of water canal to 19.3% of calabash; two methods of Flood and Calabash, and Watering Can and Calabash was 0.2% each while three methods varied from 0.2% of Watering Can, Flood and Calabash to 0.4% of Watering Can, Furrow and Calabash. In 2000s, one method varied from 0.2% of drip to 16.4% of sprinkler irrigation. Farmers that practised two methods varied from Watering Can and Furrow (0.2%) to Flood and Gravity (3.3%) while three methods of irrigation varied from 0.2% each of sprinkler, flood and calabash; and watering can, furrow and calabash to 3.1% of the sprinkler, watering can and flood irrigation.

In 1970s, the total use of the irrigation methods ranged from water canal (0.4%) to calabash (20%) whereas in 2000s, the total respondents that practiced these methods ranged from drip (0.2%) to sprinkler irrigation (24.7%) (Table 5). The pairwise t-test result is as follows: $t(20) = -1.95$, p 0.05, $CI_{0.95}$ -15.55, 9.25 (Table 6).

Table 2: The sources of water supply for Irrigation in Sokoto-Rima River Basin

S/N (%)	Source of Water	Number of Respondents	Percentage
1	River	59	13.1
2	Hand-dug Well	54	12.0
3	Earth dam	1	0.2
4	Large dam	25	5.6
5	Tube Well	21	4.7
6	Rivers/Hand-dug well/Borehole	13	2.9
7	Rivers/Hand-dug Well	27	6.0
8	Rivers/Tube Well	2	0.4
9	Hand-dug Well/Tube Wells	5	1.1
10	Hand-dug Well/Borehole	13	2.9
	Total	220	48.9

Table 3: The total of each source of water supply for Irrigation in Sokoto-Rima River Basin

S/N	Source of Water	Number of Respondents	Percentage (%)
1	River	101	22.4
2	Hand-dug Well	112	24.9
3	Earth dam	1	0.2
4	Large dam	25	5.6
5	Tube Well	28	6.1
6	Borehole	26	5.8

Table 4: Method of irrigation in Sokoto-Rima River Basin

S/N	Irrigation method	Practised in the 1970s		Practised in 2000s		Difference (%)
		Number of Respondents	Percentage	Number of Respondents	Percentage	
1	Sprinkler	5	1.1	74	16.4	15.3
2	Watering Can	12	2.7	-	-	-
3	Furrow	3	0.7	-	-	-
4	Flood	24	5.3	2	0.4	-4.9
5	Drip	4	0.9	1	0.2	-0.7
6	Calabash	87	19.3	12	2.7	-16.6
7	Gravity	15	3.3	53	11.8	8.5
8	Water Canal	2	0.4	24	5.3	4.9
9	Flood/Calabash	1	0.2	-	-	-
10	Watering Can/ Calabash	1	0.2	-	-	-
11	Watering Can/Flood/ Calabash	1	0.2	-	-	-
12	Watering Can/Furrow/ Calabash	2	0.4	1	0.2	-0.2
13	Watering Can/Furrow	-	-	1	0.2	-
14	Sprinkler/Calabash	-	-	8	1.8	-
15	Sprinkler/Watering Can	-	-	3	0.7	-
16	Sprinkler/Gravity	-	-	2	0.4	-
17	Flood/Gravity	-	-	15	3.3	-
18	Sprinkler/Flood/ Calabash	-	-	1	0.2	-
19	Sprinkler/Watering Can /Flood	-	-	14	3.1	-
20	Sprinkler/Watering Can /Furrow	-	-	9	2.0	-
	Total	157	34.7	220	48.7	-

Table 5: Total of each method of irrigation in Sokoto-Rima River Basin

S/N	Irrigation method	Practised in the 1970s		Practised in 2000s		Difference (%)
		Number of Respondents	Percentage	Number of Respondents	Percentage	
1	Sprinkler	5	1.1	111	24.7	23.6
2	Watering Can	16	3.5	28	6.2	2.7
3	Furrow	5	1.1	11	2.5	1.4
4	Flood	26	5.7	32	7.0	1.3
5	Drip	4	0.9	1	0.2	-0.7
6	Calabash	92	20	23	5.1	-14.9
7	Gravity	15	3.3	70	15.6	12.3
8	Water Canal	2	0.4	24	5.3	4.9
	Total	165	36	300	66.6	30.6

Table 6: Pairwise t-test for irrigation methods between the 1970s and 2000s in Sokoto-Rima River Basin

Irrigation methods	Paired Differences						
			95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Lower	Upper	T- value	df	Significant (2-tailed)
1970s - 2000s	-3.15	26.50	-15.55	9.25	-0.53	19	0.601

Table 7 depicts the regularity of application of irrigation water. Farmers that irrigated their farms during the wet season were 31.5%. Out of this, 30.4% irrigate when there is no rain for long period, 0.9% rarely irrigate while only 0.2% irrigates frequently. The period of irrigation varied from the crop's flowering stage (0.2%) to any crop developmental stage when there is no rainfall (13.1%) (Table 8). Twenty-eight percent (27.6%) farmers experienced rainfall after irrigating their farms. Irrigation during the wet season had negative consequences on the crops of 22.1 of the farmers. The negative consequences ranged from the destruction of furrow (0.7%) to the destruction of crops after falling down (6.6%) (Table 9).

Table 10 showed the farmers experience on irrigation farming practice in Sokoto-Rima River Basin. Farmers' experience varied from 1 to 5 years category to more than 21 years. Farmers with 21 years and above experience (17.6%) were more than any other category while those that have 6 to 10 years experience (7.1%) were the least.

Table 7: The regularity of application of irrigation water in Sokoto-Rima River Basin

S/N	Application of irrigation water	Number of respondents	Percentage
1	Frequently	1	0.2
2	Rarely	4	0.9
3	When there is no rain for long period	137	30.4
	Total	142	31.5

Table 8: Period when farmers irrigate during the wet season

S/N	Period of irrigation	Number of respondents	Percentage
1	Before rainfall onset	15	3.3
2	Crop's early developmental stage	34	7.6
3	Growth stage	4	.9
4	Flowering stage	1	.2
5	Maturity stage	29	6.4
6	At any stage when there is no rainfall	59	13.1
	Total	142	31.5

Table 9: Negative consequences of rainfall on irrigated crops during the wet season

S/N	Negative consequences	Number of respondents	Percentage
1	Crops become too wet and died	26	5.7
2	Crops are destroyed after falling down	30	6.6
3	It results in less yield after falling down completely	7	1.6
4	It causes soil erosion especially when crops are young	11	2.4
5	It causes onion disease	4	0.9
6	Retardation of growth	5	1.1
7	Destruction of crops especially at the younger stage of development	5	1.1
8	It destroys furrows	3	.7
9	It causes flooding (crops are submerged)	9	2.0
	Total	100	22.1

Table 10: Farmers experience on irrigation farming practice in Sokoto-Rima River Basin

S/N	Years	Number of respondents	Percentage
1	1 to 5	33	7.3
2	6 to 10	32	7.1
3	11 to 15	42	9.3
4	16 to 20	34	7.6
5	21 and above	79	17.6
	Total	220	48.9

DISCUSSION

The sources of water for irrigation farming include rivers, hand dug wells, boreholes, earth dam, large dams and tube wells respectively in the study area. The sources of water used by farmers varied from one to three. The result obtained showed that 35.6% of the sampled farmers used one source of water supply while 13.3% used more than one source. This is an indication that a single source accounted for 73% of total water supply sources. The total number of farmers using each source of waters either singly or in combination shows that hand-dug wells followed by rivers are the most important for irrigated agriculture. Two sources constituted 72.7% of the total water sources. Others including boreholes, earth dams, large dams and tube wells ranged from 0.2% to 6.2%. Hand-dug wells were used more than rivers possibly because most farmers were not close to rivers. Besides, some rivers are seasonal in nature and dry up during the dry season. Though the use of hand-dug well was famous, rivers were used more among the farmers that are involved in only one source**.** The farmers' use only borehole in combination with other sources of water supply but not in isolation. The combination of rivers and hand dug wells were used more than the other combinations. The inadequacy of boreholes, earth dams, large dams was due to the farmers inability

to meet the huge investment needed for their provision.

As shown in the result, 48.9% of the farmers' practice irrigated agriculture. This is about half of the farmers that were involved in rain-fed agriculture**.** According to Alvaro *et al.* (2009),
rain-fed agriculture accounted for 97 percent of sub-Saharan Africa**.** Baba (1993) noted that irrigation became a necessity due to insufficient rainfall for crop growth**.** Buttressing the importance of irrigated agriculture, IPCC (2007) reported that rain-fed agricultural yields could decline to fifty percent by 2020 in several countries of Africa.

The method of irrigation used in the 1970s in Sokoto-Rima River Basin includes sprinkler, watering can, furrow, flood, drip, calabash, gravity and water canal. Some of the traditional techniques including gravity and calabash/bucket methods used in some in northern parts of Nigeria were identified by Yahaya (2002). The calabash was the most popular single irrigation method in the 1970s while the sprinkler irrigation (the most widely used) was followed by gravity methods in the 2000s. The use of calabash alone accounted for 57.3% of the total single irrigation methods and 55.6% of all the methods used in the 1970s. But in the 2000s, sprinkler and gravity accounted for 77% of single irrigation methods and 74.2% of all the methods. Calabash usage reduced by 16.6% from 19.3% to 2.7% while sprinkler increased by 15.3% from 1.1% to 16.4%. This is an indication that modern irrigation has replaced most of the past irrigation systems. These irrigation methods include drip, tube-well, corrugation, surface, sprinkler irrigation and so on (Cox and Akin, 1979; Yahaya, 2002).

Combining different irrigation method was neither popular nor common in the past, as only 1% of the farmers were involved in combined irrigation methods in the 1970s. The methods combined include the watering can, furrow, and calabash method; watering can, flood, and calabash; watering can and sprinkler, watering can and furrow, watering can and calabash; as well as flood and calabash respectively. However, the use of multiple irrigation methods has increased tremendously in the 2000s. The three most important combinations used were flood and gravity methods; sprinkler, watering can and flood methods as well as sprinkler, watering can and furrow methods. They constitute 71% of the combined methods used. Generally, calabash method accounted for 56% of the total methods in use in the 1970s while sprinkler and gravity accounted for 61% of the methods in the 2000s. All the combinations used in the 1970s with the exception of the watering can, flood, and calabash are no longer in use presently.

The most methods of irrigation in the basin have increased in recent time. Sprinkler increased by 15.3% while gravity and water canal increased by 8.5% and 4.9% respectively. The total farmers practising sprinkler irrigation either singly or combined has increased by 23.6% while others, ranging from flood to gravity increased by 1.3% to 12.3%. On the other hand, drip and calabash irrigation methods decreased by 0.7% and 14.9% respectively. The use of drip irrigation reduced from 0.9% to 0.2% possibly because the system is too sophisticated. A drip irrigation system directly waters plants base by seeping into the roots, drop by drop and by watering only each individual item. Famers might opt for systems that appear to be less laborious.

More than half of the total number of farmers involved in irrigation method in the 1970s in the river basin used calabash method. The calabash usage alone made up of 20% while all other methods accounted for 15.7%. In the 2000s, sprinkler and gravity were mostly practised. These two methods accounted for 40.3%, with sprinkler taking the lead with 24.6%. The other six methods made up of 25.3%. The sprinkler was mostly used possibly because of water saving. Haq (1990) noted that sprinkler irrigation saves thirty percent water than surface irrigation**.** Corroborating the findings of Hag (1990), Rana *et al.* (2006) reported that the railgun sprinkler irrigation system has maximum water application and water use efficiencies than furrow method**.** The pairwise t-test showed that there is no significant difference between the irrigation methods in the 1970s and 2000s as observed during the study period

This study revealed that 31.5% of the farmers' in the river basin irrigate their farms during the wet season. Out of this, 30.4% irrigate when there is no rain for long period. The sampled farmers were asked when they irrigate their farms during the wet season. An examination of responses revealed that farmers irrigate before rainfall onset and at every crop developmental stage. Farmers that irrigate at any crop developmental stage when there is no rainfall and during the crop's early developmental stage accounted for about two-thirds of the farmers irrigating during the wet season.

The majority of the farmers (30.9%) experienced rainfall after irrigating their farms, out of which 22.1% observed that such rainfall had negative impacts on their crops. The consequences include the destruction of crops after falling, death of crops due to over wetness, soil erosion especially when crops are young, reduction in the yield of crops, retardation of growth, onion disease, destruction of furrows as well as submergence of crops through flooding. The destruction of crops after falling and death of crops due to over wetness accounted for 2.3% of the total impacts.

The variation in the categories of the farmers experience showed that the highest percentage (17.6%) in the basin has been involved in irrigation farming for over 21 years. This is equivalent of 35.9% of the farmers practicing irrigated agriculture. According to a local adage, experience is the best teacher. The farmers are well-knowledgeable in managing their irrigation activities. The consequences of irrigating during the wet season could limit agricultural production if not properly managed. Therefore, the farmers with low experience need to learn from the more experienced ones in order to reduce the effect of rainfall on crops during the wet season. The entry into irrigation farming for the past 20 years is almost stable except for those with 11 to 15 years that were higher.

CONCLUSION

The study has shown that about half of the farmers' in Sokoto-Rima River Basin practices irrigation farming, with about three-quarters using one source of water supply. Hand-dug wells and rivers were the most important sources for irrigated agriculture. Irrigation varied from one to three methods and increased by 14% over time. Some were no longer in use while newly ones emerged. Calabash and Sprinkler were the most widely used

methods in 1970's and 2000's respectively. Pairwise t-test has shown no significant difference between the irrigation methods in the different period studied. About one-third of the farmers irrigate during the wet season but 30.4% irrigate when there is no rain for long period. Irrigation period varied in the crops developmental stage but more farmers irrigate at any stage when there is no rainfall. Twenty-eight percent farmers experienced rainfall after irrigation and it resulted in negative consequences on the crops. The destruction of crops after falling down was greatest consequences experienced. Farmers' experience varied from 1 to 5 years category to more than 21 years but the highest (21 years and above) were more than any other category.

RECOMMENDATIONS

The use of hand-dug wells and rivers as major sources of water supply for irrigated agriculture could limit agricultural production to a small-scale. Large-scale irrigation farming should be encouraged through adequate provision of boreholes, earth dams, large dams and tube wells. An increase of 14% in irrigation methods within a period of 40 years is an indication that irrigation would increase significantly over time if farmers are encourage with incentives. Besides, modern irrigation method is encouraged as this would offer the potential for increased agricultural production needed to combat food insecurity. The consequences of irrigating during the wet season could limit agricultural production if not properly managed. Therefore, the farmers with low experience need to learn from the more experienced ones in order to reduce the effect of rainfall on crops during the wet season.

REFERENCES

Adejuwon, J.O., 2015. An assessment of the changing pattern in the choice of vegetable varieties in Sokoto-Rima River Basin, Nigeria: Pepper. *International Journal of Ecology and Environment Studies,* 3(2), 7-15

Adejuwon, J.O. 2017: An assessment of the changing pattern in tomato cultivation in Sokoto-Rima River Basin, Nigeria. *Applied Tropical Agriculture,* 22 (2), 88-93.

Alvaro, C., Tingju, Z., Katrin, R.., Richard, S.J., Claudia, R., 2009. *Economy-wide impact of climate change on Agriculture in Sub-Saharan Africa.* International food policy research Institute (IFPRI) discussion paper, No: 00873 p1.

Baba, M. K., 1993. Irrigation Development Strategies in sub-Saharan Africa: A comparative study of the traditional and modern irrigation system in Bauchi State, Nigeria. *Ecosystem and Environment* 45, 47-58.

Cox, A., Akin, N., 1979. *Agricultural Ecology: An Analysis of World Food Production:* San Francisco, Freeman Press.

De Silva, S., 1998. *Reservoirs of Sri Lanka and their fisheries.* UN Food and Agriculture Organization. http://www.fao.org/docrep/003/T0028E/T0028E03.htm.

Dillehay, T.D., Eling, H.H Jr, Rossen, J. 2005. Preceramic irrigation canals in the Peruvian Andes. *Proceedings of the National Academy of Sciences* 102 (47), 17241–4. doi:10.1073/pnas.0508583102. PMID 16284247

Emielu, S.A., 2000. Senior Secondary

Geography. Geographical Bureau Nigeria Limited, Ilorin. pp 71-72.

FAO (Food and Agriculture Organization of the United Nations), 2011. AQUASTAT online database. Rome, FAO. http://www.fao.org/nr/water/aquastat/data/query/index.html

FAO, 2017. The Future of Food and Agriculture: Trends and Challenges. www.fao.org/3/a-i6583e.pdf

Federal Ministry of Water Resources (FMWR), 1991. *Water Resources Development: The Journey So Far* (1985-1993). Network Communication Ltd, Kaduna.

Frenken, K., 2005. *Irrigation in Africa in figures – AQUASTAT Survey – 2005" Food and Agriculture Organization of the United Nations.* ftp://ftp.fao.org/agl/aglw/docs/wr29_eng.pdf.

Haq, N., 1990. *Evaluation of Modern Irrigation Techniques for Sandy Loam Soil having Low Slopes.* M.Sc Thesis, Dept. of Irrigation and Drainage, University of Agriculture, Faisalabad. IGRAC (International Groundwater Resources Assessment Centre). 2010. Global Groundwater Information System (GGIS). Delft, The Netherlands, IGRAC.

Intergovernmental Panel on Climate Change (IPCC), 2007. *Climate Change 2007: Synthesis Report. Summary for policymakers*, available at: http: // www. Ipcc-wg1-ucar.edu/wg1/w1-report.htm, pp. 1-22.

Needham, J., 1986. *Science and Civilization in China*: Volume 4, Physics and Physical Technology, Part 2, Mechanical Engineering. Taipei: Caves Books Ltd. Pages 340-346

Negm, A.M., 2017. The Nile River, Springer, 741pp.

Raghunath, H.M., 2006: Hydrology: Principles, Analysis and Design. New Age International (P) Ltd. Publishers, New Delhi; 2nd edition, 476pp. https://books.google.com.ng/books?isbn=8122418252

Raghunath, H.M., 2007. Ground Water. New Age International (P) Ltd. Publishers, New Delhi. https://books.google.com.ng/books?isbn=8122419046)

Rana, M. A., Arshad, M., Masud, J., 2006. Effect of Basin, Furrow and Raingun Sprinkler Irrigation Systems on Irrigation Efficiencies, Nitrate-Nitrogen Leaching and Yield of Sunflower. *Pakistan Journal of Water Resources*, 10(2), 1-7

Rosenberg, M., 2017: Strategy and Geopolitics: Understanding Global Complexity in a Turbulent World. Emerald Group Publishing, 301pp.

Seok-gi, B., 1987. *Jang Yeong-sil 장영실.* Woongjin Wiin Jeon-gi 웅진위인전기 11. Woongjin Publishing Co., Ltd.

Siebert, S., Burke, J. Faure, J., Frenken, K., Hoogeveen, J., Döll, P., Portmann, T., 2010. Groundwater use for irrigation – a global inventory. Hydrology and Earth System Sciences., 14, 1863–80.

The World Water Organization, 2010. Water Facts and Water Stories from Across the Globe. Accessed Dec 4, 2017. http://www.theworldwater.org/water_facts.php 2

UNESCO, 2016. The United Nations world

water development report 2016: Water and jobs. UNESCO Publishing, 148pp.

UNESCO-WWAP, 2012. Managing Water with Uncertainty and Risk. Facts and Figures from the United Nations World Water Development Report 4. Published by the United Nations World Water Assessment Programme.

World Water Assessment Programme, 2009. The United. Nations World Water Development Report 3: Water in a. Changing World. Paris: UNESCO

Yahaya, M.A., 2002. Development and challenges of the Bakolori Irrigation Project in Sokoto State, Nigeria. *Nordic Journal of African Studies* 11(3), 411-430